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TITLE: ACCELERATION OF ^{14}C BEAMS IN ELECTROSTATIC ACCELERATORS

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ACCELERATION OF ^{14}C BEAMS IN ELECTROSTATIC ACCELERATORS

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ABSTRACT

Operational problems in the production and acceleration of ^{14}C beams for nuclear structure research in Los Alamos National Laboratory's Van de Graaff accelerators are discussed. Methods for the control of contamination in ion sources, accelerators and personnel are described. Sputter source target fabrication techniques and the relative beam production efficiencies of various types of bound particulate carbon sputter source targets are presented.

I. INTRODUCTION

The accelerated ^{14}C beam has proven to be a powerful research tool at Los Alamos National laboratory's Van de Graaff facility. Two stage acceleration of ^{14}C began in February 1979 and three stage acceleration in July 1980.

The safe production of a ^{14}C beam is made possible by the development of the sputter ion source.[1] Two of these ion sources are used at the facility. One, a General Ionex model 834 HICONEX sputter ion source,[2] is used on the vertical Van de Graaff; and the other, a Middleton type sputter ion source built at the University of Pennsylvania,[3] is used with the tandem Van de Graaff. Because of the problems presented by ^{14}C's radioactivity, methods were explored for the optimization of beam production by using a minimum of target material. The sputter target holders (cones) of the ion sources were redesigned to a reflection type geometry. Examples of the cones are shown in Figure 1. The cone on the left is used in the vertical ion source. In this ion source the positive cesium beam is steered off-axis through the hole in

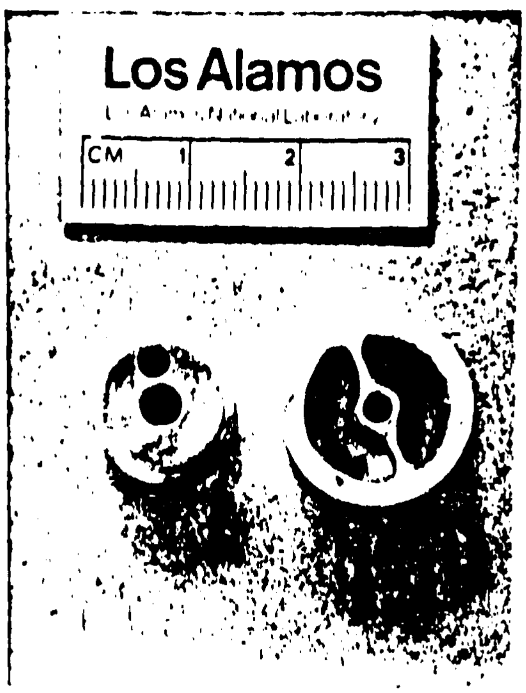

Fig. 1 Reflective geometry sputter source cones

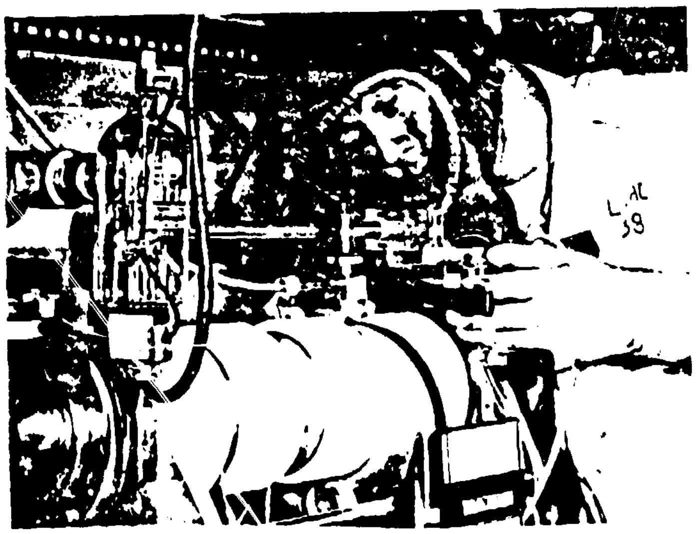

Fig. 2 Maintenance on tandem's sputter source

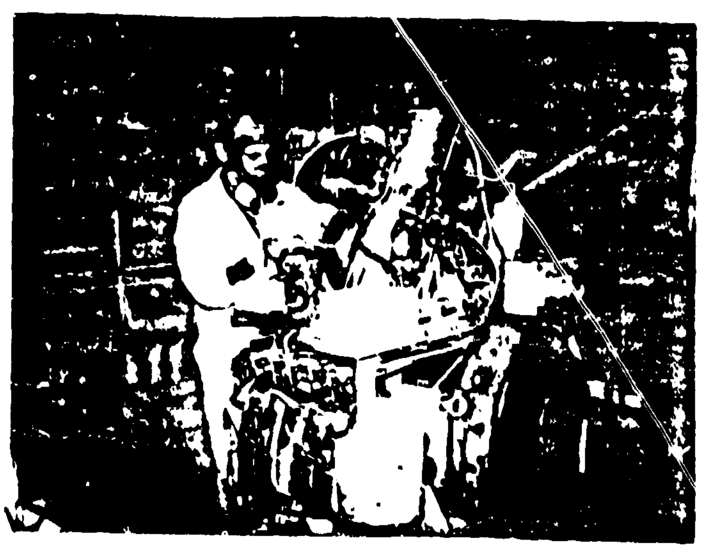

Fig. 3 Maintenance on vertical's sputter source

the cone. It is then electrostatically reflected towards the backside of the cone where it is focused onto the target pellet. The tandem sputter cone is shown on the right in Figure 1. In this source the cesium ionizer, cone, cesium reflector electrode, and sputter target all lie on a common axis.[4]

II. RADIOACTIVE MATERIAL HANDLING AND CONTAMINATION CONTROL

Prior to the first use of the ^{14}C beam the problems of safe handling of ^{14}C and control of contamination were carefully studied. The principal hazard from ^{14}C is the beta radiation received from inhaled or ingested ^{14}C. Proper training and work procedures can prevent ingestion. Full facemask respirators equipped with high efficiency filters can prevent inhalation of ^{14}C if the carbon is in a particulate form. If the ^{14}C were in the form of a gaseous compound then a supplied air breathing apparatus such as a bubble suit would be required.

The ^{14}C as received is in the form of carbon black. Therefore, the principal personnel health hazard will be from ^{14}C in a very fine particulate form. Consequently, anytime personnel work on ^{14}C contaminated components, the components must be in an approved hood equipped with a HEPA filter. Figures 2 and 3 show personnel wearing respirators, and working on the ion sources. Figure 4 shows work being performed in the filtered hood.

Fig. 4 Work being performed in a filtered hood

The beta particle emitted by ^{14}C has a maximum energy of 156 keV. This allows easy detection of surface contamination by standard beta detectors. Surface contamination on the outside of the ion source can be removed by washing with common solvents.

The insides of the ion sources are the main areas of high levels of contamination. In the tandem ion source most of the contamination is found downstream of the sputter target with exception of the areas immediately around the tip of the cesium ionizer. The vertical ion source, however, shows heavy contamination over most of its internal components. In the case of the cesium ionizer and reservoir region the contamination appears to be implanted into the surface of the metal, and therefore, is not easily removed.

The low energy beam line of the tandem shows detectible but very low levels of contamination. The beamline Faraday cups, terminal stripper foils, and experimental targets have not shown detectible ^{14}C contamination. The accelerator tube of the vertical Van de Graaff, however, does show considerable contamination.

III. BEAM PRODUCTION EFFICIENCIES OF SPUTTER SOURCE TARGETS

Before ^{14}C was first used in the tandem sputter source identical sputter source cones were tested with ^{13}C substituted for the ^{14}C. These tests were very successful showing good ^{13}C beam production. However, when the ^{14}C cones were actually used the results were less than anticipated.

An experiment was designed to measure the relative difference in yields. The tandem sputter source was used for the measurements. The on-axis reflection geometry cone was used as shown in the right of Fig. 1. Five cones were made.

The reference cone was made by machining a 'pill' of solid graphite and pressing this into the substrate. The other four targets were made exactly as the method developed from ^{14}C cone production.[4] The cone 'pill' materials used were:

1. ^{12}C Carbon black (Lampblack)[5]
2. Elemental ^{13}C [6]
3. ^{14}C Carbon black [7]
4. Ground graphite

These materials were mixed with the binder in the amount of 100 mg carbon to 30 mg binder. In addition, an older ^{14}C cone was also included in the experiment.

The measurements were made on three days scattered throughout a period of a month. After an initial short outgassing period the output of the solid graphite cone stayed relatively constant with respect to cesium reservoir temperature and was used as a reference. For cones other than that of ^{12}C the atomic beam outputs quoted refer to the output of the isotopic beam plus the ^{12}C contaminant beam. The ^{12}C contaminant varied from 26% to 40% depending on the impurities. The binder contributes an ^{12}C impurity of 16%. The measurements were made by letting the reservoir temperature stabilize and then tuning the beam from each cone for a maximum. The extraction voltage was left constant. Adjustments were made in cone position, lens voltage and reflection voltage. In practice, very little changes in the source parameters were necessary from cone to cone for a given temperature. The output currents were measured on the low energy cup of the tandem after being analyzed by the 30° inflection magnet. The distance from the sputter source to the cup is 6m and is far from optimum in beam transport efficiency. Hence, the outputs quoted should only be considered as relative. Uncertainties in the measured outputs cannot be easily determined since errors in the tuning of various source parameters are involved. In addition the temperature of the cesium reservoir is not necessarily a good indication of the amount of cesium beam in the source. However, by using the output of the solid graphite target at the reservoir temperature of 180° the uncertainty in the reproducibility of the atomic beam over the three days is ∿6%. It is hoped that errors in tuning are small.

One of the major effects noted during the measurements and previously observed during the ^{14}C runs is that the cones made from carbon black condition with time in the source, i.e. their outputs grow from one running time to the next. This is shown for the ^{12}C carbon black cone in Fig. 5. The lines are to guide the eye only. The result is similar for the ^{14}C carbon black cone. This does not appear to be caused by outgassing of the cone since measurements of the ^{16}O beam have shown very small amounts present. The improvement in beam output may be due to the presence of the cesium beam although just letting the cones remain in the source appears to have beneficial effects.

The other main characteristics of the carbon black cones is also shown in Fig. 5. This is the characteristic decrease in output as the cesium current is increased. This effect continues until the cone has been in the source for a long period of time. This is shown in Fig. 6 where the output of the old ^{14}C cone behaves very similarly to that of the graphite cones.

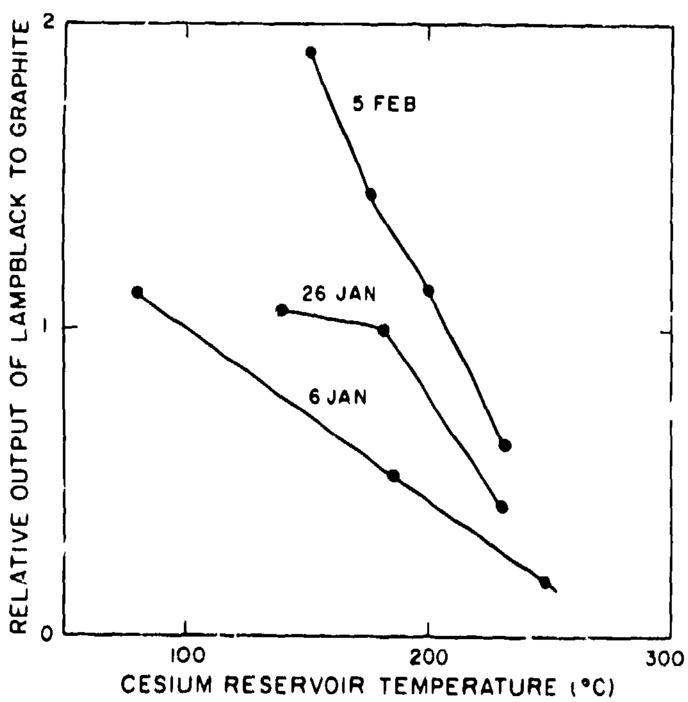

Fig. 5 Carbon black cone conditioning

Another interesting effect is that the ^{13}C cone has the highest output of any of the tested cones as shown in Fig. 6. Since this cone was made in identical fashion to the rest of the cones the relatively large beam output must be caused by the form of the the ^{13}C. Carbon black is made by burning hydrocarbons or wood, in the case of the ^{14}C by burning acetylene. The ^{13}C produced by Mound Facility is made by converting CO_2 into carbon in the presence of hydrogen by using iron as a catalyst.[8] The iron-carbon mixture is separated in the presence of HCl.

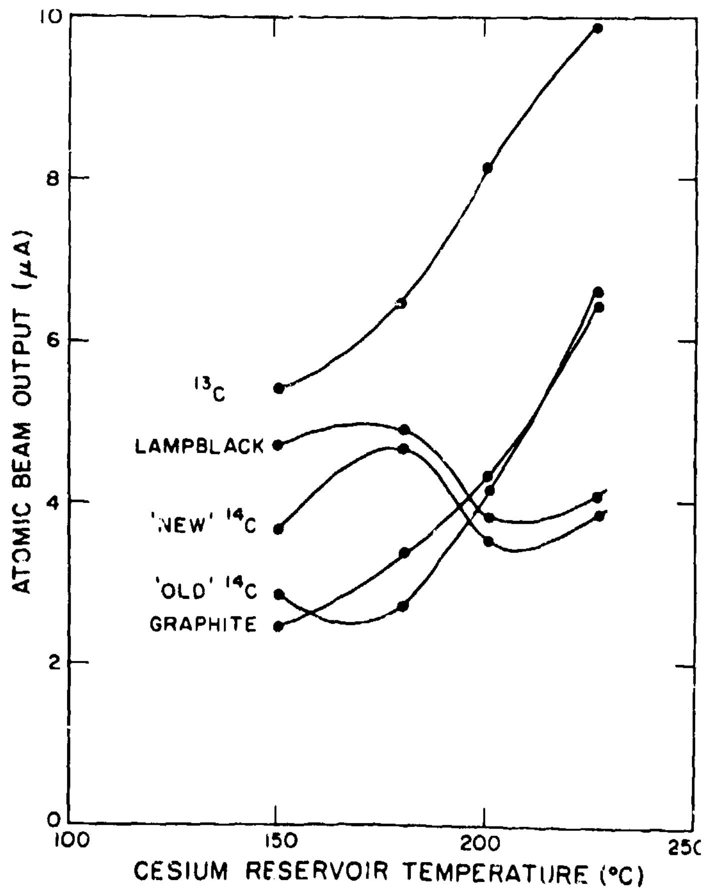

Fig. 6 Atomic beam output v.s. cesium reservoir temperature

The ratio of the total molecular yield (e.g. for a ^{14}C cone--$^{12}C_2$+ (^{12}C + ^{14}C) + $^{14}C_2$) to the atomic yield is also of interest since it is possible that some of the strength from the atomic beams might be transfered to making molecular beams. Only the diatomic beams were measured. The ratio of total carbon diatomic molecular beam output to total carbon atomic beam output is given in Table 1 for a reservoir temperature of 200°C. The chosen temperature is arbitrary since the ratio changes very little with the reservoir temperature and no trends are easily seen.

TABLE 1

Ratio of Diatomic Beam to Atomic Beam Output.

Cone Material	Ratio
Graphite	.52
Ground Graphite	.45
Carbon black	.27
^{13}C	.21
'New' ^{14}C	.30
'Old' ^{14}C	.42

Unfortunately, the ratios for the various source target materials show no correlation to the atomic beam outputs.

Summary

Safe handling of ^{14}C materials and contaminated ... ents is done similarly to those contaminated ... tritium. The greatest hazard in handling ^{14}C is in breathing the particles. Respirators with full face masks and high efficiency filters are used to prevent inhalation. Contamination can be detected in many parts of the low energy beam handling systems and in the vertical accelerator's acceleration tube.

It's desirable to use as little ^{14}C as possible to prevent undue contamination and, therefore, reduce safety hazards. The form of the elemental carbon used in the source cone fabrication is very important in determining the amount of atomic beam output. The form of carbon supplied by Mound Facility for the ^{14}C target is far superior to anything else tested.

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